Artificial Intelligence Techniques for Semi-Automated Forces Based on Potential Tactics

SBIR Phase I Final Report
Topic A95-069

Contract Number: M67004-96-C-0011
CDRL 0002AB

October 4, 1996

By:
Richard Stottler
Spencer Menlove
Drew Downes

Stottler Henke Associates, Inc. (SHAI)
2016 Belle Monti Avenue
Belmont, CA 94002
(415) 655-7242
FAX (415) 655-7243

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)

2. REPORT DATE
3 OCT 1996

3. REPORT TYPE AND DATES COVERED
Final Report 02/05/96-09/30/96

4. TITLE AND SUBTITLE
Reports/Technical Data
Final Report

5. FUNDING NUMBERS
C-M67004-96-C-0011

6. AUTHOR(S)
Richard Stottler
Spencer Menlove
Drew Downs

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Stottler Henke Associates, Inc.
2016 Belle Monti Avenue
Belmont, CA 94002

8. PERFORMING ORGANIZATION REPORT NUMBER
No.104

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US. Army Simulation, Training and Instrumention Command
12350 Research Parkway
Orlando, FL 32826-3276

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

19990628 118

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (*Maximum 200 words*)
In this Phase I SBIR research we proved the feasibility of a graphical tactics language. We showed through a proof of concept prototype that tactics in this language can be entered in a graphical tactics editor. We also showed that these tactics can be used to implement tactical formations appropriate to arbitrary terrain, and that they can control SAF movement. We researched armor doctrine and tactics from a variety of sources and cultures that are not currently used to control SAF in U.S. Army simulations. We used these tactics to determine which tactics are most naturally expressed and manipulated graphically, and also used them to define the capabilities and expressiveness necessary in a graphical tactics language. We also ceated a demonstration data base of these tactics using the graphical tactics language and showed that case Based reasoning can be used to automatically select tactics appropriate to a given terrain. We used a simulation that responds to a subset of commands available in ModSAF and provides a subset of the information available in ModSAF to develop a SAF controller.

14. SUBJECT TERMS

Tactics	Graphical Language
MODSAF	Simulation
SAF	Training

15. NUMBER OF PAGES
37

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
UNCLASSIFIED

18. SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

19. SECURITY CLASSIFICATION OF ABSTRACT
UNCLASSIFIED

20. LIMITATION OF ABSTRACT

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A. Introduction

The current Semi-Automated Forces (SAF) OPFOR does not provide realistic interactive opponents for the Close Combat Tactical Trainer (CCTT) and ModSAF based simulations. This is because current SAF OPFOR are based on Soviet Doctrine utilized in Central Europe. The U.S. Army does not anticipate meeting an army based on Soviet Doctrine in Central Europe, therefore the Army requires a more varied SAF OPFOR. The unbounded domain of all potential infantry tactics precludes an exhaustive state space search for deriving optimal tactics, so a modern SAF OPFOR should be based on the varied doctrines and terrains that exist in the world. The best potential tactics are dependent on weather, equipment, terrain, and many other factors. A large pool of potential tactics needs to be available, and there must be a way of selecting the best tactics from this pool for a given situation. This will result in an effective and unpredictable SAF OPFOR which is based on the conditions and equipment the OPFOR is given. Friendly SAF must also behave in a realistic manner in a wide variety of situations for an effective training experience. This means that all SAF need a rapid, easy means of producing behavior and must be created to allow an effective training environment.

B. Summary

In this Phase I SBIR research we proved the feasibility of a graphical tactics language. We showed through a proof of concept prototype that tactics in this language can be entered in a graphical tactics editor. We also showed that these tactics can be used to implement tactical formations appropriate to arbitrary terrain, and that they can control SAF movement. We researched armor doctrine and tactics from a variety of sources and cultures that are not currently used to control SAF in U.S. Army simulations. We used these tactics to determine which tactics are most naturally expressed and manipulated graphically, and also used them to define the capabilities and expressiveness necessary in a graphical tactics language. We also created a demonstration data base of these tactics using the graphical tactics language and showed that case based reasoning can be used to automatically select tactics appropriate to a given terrain. We implemented a demonstration simulation that responds to a subset of commands available in ModSAF, and that provides a subset of the information available in ModSAF. Finally we used this simulation to develop a SAF controller that works on a level appropriate for easy integration with Army simulations, and that directs SAF behavior according to tactics created by the editor.

C. Conclusions

The Graphical Tactics Editor makes tactics very easy to create and edit. This makes it feasible to create a large database of potential tactics. Creating this database and then drawing SAF behaviors from it is a way to create varied, intelligent, and appropriate SAF for any given situation. The Phase I tactics editor and SAF controller focused on armor tactics at the company level, but the concepts are easily expandable for widely varied engagement scales and unit types. The run-time computational load for the system is on the order of the number of units being controlled, so it was not a significant burden on simulation resources.

1. PHASE I INVESTIGATION

1.1 The Domain

Our first task within our Phase I effort was to work with the Army to determine a domain that could benefit from the use of SAF tactics. Through discussions with Army personnel, a consensus was formed on the particular focus for Phase I. The primary focus for Phase I was armor tactics. The armor training domain was selected because of its relative importance as well as the existing simulation training available for tank crews. Additionally, the need to interface to ModSAF or CCTT in the Phase II system was cited as an important consideration.

We began our investigation into the domain by reviewing numerous Army documents pertaining to the simulation training community, diverse armor doctrines, and the specifications and capabilities of existing SAF. These documents and a knowledge engineering trip to observe National Guard armor simulation training at Fort Knox provided some insight into the range of tasks the SAF must engage in, as well as the interplay between the SAF and SAF operators. As a result of these observations and investigations into ModSAF capabilities, we deigned the SAF control to operate at a higher abstraction level than current SAF control software. This way the SAF are controlled at a high, tactical level by our software. This software in turn makes calls to existing SAF functionality and in this way we avoid redundant effort with existing systems, and we are able to build intelligent overall behavior by the symbiosis of intelligent sub-behaviors acting in a tactically directed effort. It became clear that this tactical direction should be the focus of the Phase I effort.

1.2 The Role of Simulations

The first U.S. military action following the Cold War resulted in a decisive victory for the United States. The commander of Desert Storm received a ticker tape parade in New York City. The casualties were lower than would be expected in garrison back in the United States. The entire ground campaign was completed in less than 100 hours. This great success reminds one of the Panzer Divisions rolling to victory over the Polish cavalry. Five and a half years later, these same Panzer Divisions could not prevent the Red Army from taking Berlin.

Simulations provided some of the roots to American victory in Desert Storm. On 2 August 1990, war game designer Mark Herman was working on modeling Desert Storm using a commercial game called *Gulf Strike*. A series of simulations using *Gulf Strike* predicted that the Allies would prevail in 96 hours and would take very low casualties. During Desert Shield and Desert Storm, a simulation called *Tacwar* was run on a daily basis. *Tacwar* was used to help plan the logistics needed to support the last-minute redeployment that allowed the ground attack that outflanked the Iraqi Army in Kuwait. Simulations also provided important training to individuals and units before deployment to Desert Storm. The National Training Center provides the most realistic simulation of modern combat available any where in the world. All of these simulations were effective when fighting the Iraqi Army.

U.S. Army simulations depend on Soviet doctrine when simulating the enemy. In the new global environment that resulted from the end of the Cold War, Soviet doctrine still describes the tactics of such powers as Iraq, Syria, Libya, and North Korea. Some powers such as Egypt, which in the past used Soviet doctrine, will use Western doctrine in the future. Powers such as the Bosnian Serbs, Iran, and China, which were never in the Soviet block, have never used Soviet doctrine. Since we can no longer define the threat as using Soviet doctrine, simulations need to start using multiple doctrines from many different parts of the world.

In order to allow for different doctrines, additional tools should be designed to work with our simulators. For example, a case-based reasoning tool could be built that allows selection of appropriate tactics based on different doctrines. This tool could prioritize tactics and set correct parameters. A case-based reasoning tool could also provide the ability to analyze terrain and select a starting position for the implementation of a tactic.

These new tools would enhance simulators in a number of ways. First, different behaviors based on different doctrines could be implemented in Army simulators. This would provide soldiers with a greater range of experience. A greater range of experience would increase the chance of recognizing a tactic and avoiding unpleasant consequences that result from a particular tactic. A greater range of experience would decrease the chance of surprise in combat when faced with a new or novel tactic. Second, different tactics based on different doctrines could lead to more training opportunities. Soldiers would see different behaviors out of the opposing force. This would make it difficult for soldiers to go into the simulator knowing how the enemy will react. Third, better entry tools would allow for quicker entry of new tactics and doctrines as they are developed around the world. Fourth, new tools could enhance the capabilities of Semi-Automated Forces (SAF) operators when operating opposing forces during training exercises.

The choice of armor doctrine for study relies on a number of factors. Simulators using armor doctrine are readily available and a stable technology. This allows for immediate testing of the software developed during this project. In addition, historical and technical written material on armor doctrine is widely available.

1.3 The Relationship Between Simulators and Doctrine

Simulations can be used with none, one, or both sides being run by the computer. In general, simulations used for training have the trainees manning simulators and the opposing force run by the computer. The soldiers implement US Army doctrine as defined by Training and Doctrine Command (TRADOC). The computer uses Soviet doctrine as defined by intelligence agencies and defectors. The computer can be aided by human operators. When a human operator helps run the opposing force, the force is known as a semi-automated force (SAF).

The requirement for human operators comes from the limitations of the computer as a thinking entity. It has proven difficult to realize intelligent behaviors on current computers though some limited applications have been demonstrated - the ability to play chess, for example. Chess is an

extremely limited game when compared to a military simulation. Therefore, the algorithms used to power a chess program will not work for a military simulator.

Humans have several abilities difficult to reproduce in computers. An important human ability is correctly recognizing patterns. In terms of a simulation, the soldiers in the simulator perform a certain maneuver. This maneuver could lead to several options down the road. A human operator can normally determine what the soldiers intend to do next, this has proved difficult for computers. The human operator will be tougher to deceive and fake out of position.

The human operator uses the options available in the simulation. The opposing force in our current simulators use Soviet doctrine. This limits the operator's choice of options to those available in Soviet doctrine.

Simulations must take into account many variables including: organization, morale, terrain, weather, supply, movement, fire, equipment, doctrine, etc., When a variable changes, the simulation needs to change. The Cold War ended in the beginning of the 1980s. American doctrine changed to reflect this situation. However, the doctrine in our simulations still reflect Soviet doctrine from the Cold War.

1.4 Changing Doctrine

An army will change their doctrine for many reasons. Some common reasons for changing a doctrine include: political change, social change, technological change, and victory/defeat. The type of reason that drives the army to change their doctrine will shape the new doctrine that results.

Political change can modify the resources available to an army. For example, the change from the Weimar Republic to the Third Reich resulted in significant changes in German armor doctrine. The change in political direction allowed the development of the panzer divisions which proved so effective at the beginning of WWII.

Social change modifies the raw human material used by an Army. A good example of change in the society that leads to a change in the Army doctrine comes from the American army. During the Vietnam War, the lower classes in America served in greater numbers than the middle and upper classes. College and marriage deferments allowed a large segment of the American middle and upper class to skip Vietnam. The much better educated soldiers (all American soldiers have at least a high school degree) allowed the U.S. Army to change to the Maneuver Doctrine.

Technological change gets the lion's share of the attention as the cause of change in doctrine. The introduction of rifled muskets and later repeating muskets had a profound change in the doctrine of the armies that fought in the American Civil War. This change occurred during the years 1863-4. A doctrine of trench warfare developed before the end of the American Civil War.

Finally, victory or defeat sometimes leads to a change in doctrine. For example, American Army doctrine changed because of the success of the German panzer divisions at the beginning of WWII. The defeat of the British by the Germans in France and North Africa eventually lead to a change in British armor doctrine.

Given these reasons for changing doctrine, the end of the Cold War is bound to lead to changes in armor doctrine around the world. In order to account for the change in doctrines, the behaviors in our simulators will also need to change. Let's examine the changes in doctrine resulting from the end of the Cold War.

1.5 Cold War Doctrine

The Cold War actually had a rather interesting effect on military doctrine around the world. Military doctrine during the Cold War could be divided into two camps. The first camp involved the central-control model of the Soviet Union. The second camp revolved around the overwhelming firepower model of the United States. Both of these military doctrines have now begun to disappear.

The Soviet Union doctrine will soon be replaced even in Russia. This will happen because of a lack of resources required to fight war according to former Soviet doctrine. Soviet doctrine has always depended on large armies that fight with close central control. Some would liken this to a large, lumbering giant. The actual intent is to create an army that works like a symphony orchestra. Each instrument works with all the others in a closely controlled manner to create a powerful force.

To a certain extent, military doctrine reflects the society within which the army exists. Soviet society rested on a three legged tripod of the Party, State Security Agency, and the Army. All three legs of this structure reported to one man. In the formative years of the Soviet Army's doctrine, this man was Joseph Stalin.

In the 1920s, the Soviet military developed a doctrine called the "Deep Battle" under the leadership of Tukhachevsky. In the 1930s, the Soviets developed one of the best medium tanks of World War II in the T-34. In the words of General Guderian written in 1937 on page 153 of *Achtung-Panzer*: "Russia possesses the strongest army in the world, numerically and terms of modernity of its weapons and equipment." However, the Red Army almost managed to lose to the Germans.

One other event happened in the 1930s that lead to disaster in the early phases of the Russian campaign. Stalin killed most of the Soviet Union's Army officers in order to ensure control of the Soviet military. The Soviet Union has always lacked a strong non-commissioned officer corps. Stalin's elimination of a large portion of the officer corps basically left the Soviet Army without leadership. In this environment, strong central control was the only doctrinal option available to the Soviet Army.

However, times have changed in the Soviet Union. Strong central control has broken down and this includes the military. During the hay days of the Soviet Union, military spending consumed a large portion of the Soviet Unions gross national product. This will no longer hold true. Considering these important changes, you can expect to see the Soviet Union develop new doctrine. In this case, our simulators have become obsolete. Our simulators utilize a doctrine that soon will no longer exists.

American doctrine did not survive the Cold War either. American doctrine was tried with dubious results in Korea. Finally, American doctrine died in the jungles of Southeast Asia. A new American doctrine (i.e., maneuver doctrine) was reborn.

1.6 Post Cold War Doctrine

The first U.S. military action following the Cold War resulted in a decisive victory for the United States. Within this context, a major debate over maneuver warfare has raged around and within the American armed forces. In 1989, the U.S. Marine Corps issued a new basic doctrinal manual, FMFM1, *Warfighting*, which explicitly adopted maneuver warfare as doctrine. The U.S. Army had adopted many of the basic concepts of maneuver warfare as doctrine earlier, in the 1982 edition of FM 100-5, *Operations*.

New doctrine basically originates from success in war. The most likely candidate for most of the worlds doctrine comes from the model of the German Army in the years 1939 - 1942. When reviewing the current discussion of maneuver warfare, you will find words such as *auftragstaktik* and *schwerpunkt*. This German influence on modern doctrine goes as far as adding words to our vocabulary.

German armor doctrine could prove useful when loaded into our simulators. Other nations around the world have access to German armor doctrine. Some of these nations will develop a doctrine that learns from German Army during WWII. The next section begins with a discussion on how to study doctrine.

1.7 The Examination of Foreign Doctrine

Books on military history provide one of the best guides to the practical application of doctrine in combat. Doctrines without the underpinning of history tend to be long on theory and short on application. In order to develop a successful armor doctrine, there must be conflicts which allow for an army to utilize an armor force. Two conflicts would be sufficient to provide a reasonable demonstration of an open society, recorded military history, armor doctrine, and good terrain. The requirements demonstrated by the two conflicts are examined below.

When looking at each of these conflict requirements, an open society seems like a strange requirement. Consider the border conflicts between Russia and China during the 50s and 60s. These conflicts might provide good information on the utilization of armor doctrine. However,

the lack of information provided by the Russians and Chinese make studying armor doctrine impossible in the context of these conflicts.

Recorded military history provides the practical application knowledge to determine the effectiveness, usefulness, and implementation of doctrine. Time needs to pass before history can be written. Desert Storm might provide some useful lessons in the application of maneuver doctrine. More time needs to pass before the histories of this campaign will be useful for studying doctrine.

In order to study doctrine, doctrine needs to exist. Studying the 1948 Arab-Israeli War for Israeli armor doctrine would be a futile exercise. Basically, Israeli did not have an armor doctrine with which to fight the 1948 war. Israeli used on-the-job training to conduct armor operations during this war.

Finally, good armor terrain provides the last requirement for studying foreign armor doctrine. The Korean War saw the deployment of armor by both sides. The restricted terrain of the Korean peninsula does not provide very useful armor terrain. Therefore, the implementation of armor was severely limited by the terrain.

Two different doctrines were examined during the first phase of this project. The first foreign doctrine to be examined was German armor doctrine. The Germans during WWII were the best armor force in the world during the early stages of the conflict. The campaigns in Poland and France demonstrated the effectiveness of tanks in modern conflict. The pure armor campaign in the Western desert provides lessons on the use of tanks in ideal terrain conditions. The Eastern Front provides lessons in the mass use of armor which were not duplicated until the Arab-Israeli conflicts in 1967 and 1973.

The Arab-Israeli conflicts of 1967 and 1973 also provide useful lessons on the application of armor doctrine to combat. Actions on the Golan Heights and the Sinai Desert provide examples of combat in varied terrain (desert and rolling hills). Some of the largest tank battles since Kursk were fought during the Arab-Israeli conflicts.

1.8 German Armor Doctrine

The interest in German armor doctrine in the West exists for many good reasons. First, the Germans tend to be among the best in the world at the study of military history. Second, the German Army has proven very successful at fighting wars in the 19th and 20th centuries. Third, some of the best military writing by the Germans who served in WWII has been translated into English.

The German Army provides a unique history to study the relationship between doctrine and operational history. One of the chief books on armor doctrine, *Achtung Panzer!* by Heinz Guderian, has recently been translated into English. In addition, Guderian's memoirs of his WWII

service has been available since the mid-50s. This combination of doctrine and history provides a good understanding of German doctrine.

An understanding of the German Army of the time period 1920-1945 must proceed further discussion of German armor doctrine. The German Army of the time period 1920 to the early 1930s was limited to 100,000 men. This army was limited to 4,000 officers. This was very small by European standards.

The German General Staff, forbidden by the Versailles Treaty, still existed undercover. The German skimmed off the cream of the serving officers and trained them as staff officers. This meant that the German Army as an organization was well run. The tradition of the German General Staff was to study history and develop new doctrine from the lessons learned.

The popular image of the German Army being armed with weapons superior in both technology and quality has persisted. The facts support a different interpretation. The German tanks which started the war were not superior in armor or firepower to the Allied tanks they faced. When the Germans invaded Russia, they had no tank that could match the T-34s and KV-1s used by the Russians. The one difference was that each German tank had a radio receiver or radio. This allowed the Germans to destroy superior enemy tanks with superior tactics.

The Germans designed superior tanks as the war continued. The Tiger I which had very thick armor and an 88mm gun was proof against most Allied tank guns. The Panther which also had very thick front armor, good mobility, and a very good gun was also superior to most Allied tanks. During WWII, the Germans produced 24,360 tanks including 1,355 Tiger Is and 5,508 Panthers. Allied tank production during WWII was: the British produced 24,803 tanks, the Americans produced 88,410 tanks, and the Russians produced 87,200 tanks. For every tank the Germans produced, the Allies produced eight.

The German Army always made training a high priority. The German Army often fought outnumbered by their enemies. The Germans could not hope to out produce their enemies, particularly with the Americans on the side of the Allies. The German solution was to outfight their opponents. The only path to consistently outfighting your enemy comes through training. In some ways, German victories early in the war resulted from superior training and doctrine. When this training superiority began to slip late in the war, the German Army proved incapable of winning any more victories.

Armies have often been accused of fighting the last war. Many reasons exist for this cliché. Often, armies use equipment from the last war. Sometimes the wars come so fast, that armies do not have an opportunity to change. None of these hold true for the German Army in WWII. The German Army at the beginning of WWII fought a new type of war. Journalists quickly attached the name "Blitzkrieg" to this new method of war. Note that the German generals never talked about war in terms of Blitzkrieg. The roots of the new German Army's new method of war can be found in WWI.

The German General Staff never believed in the "Stab in the Back" theory of why Germany lost WWI. Instead the German General Staff, which was forbidden by the Versailles Treaty, looked for military reasons for the defeat of the German Army in WWI. One key reason the Germans lost WWI was the lack of tanks and anti-tank weapons.

Heinz Guderian may be considered as the chief architect of the armor doctrine that brought Germany success during the early part of WWII. As mentioned earlier, Guderian wrote two books that provide a clear understanding of German doctrine and operational experience in WWII. In order to understand where Guderian obtained the ideas that formed German armor doctrine, a review of his early career proves useful.

From 1931 to 1935, Guderian served as General Lutz's Chief of Staff to the Inspectorate of Motorized Troops. The Lutz-Guderian partnership proved vital to the development of German mechanized forces in the critical period before the formation of the first three panzer divisions in 1935. Although Lutz was the senior officer, Guderian was the intellectual driving force.

When the first three panzer divisions were established, Guderian was given command of the 2nd Panzer Division. This removed Guderian from the center of policy making with the Armored Troops Command. Guderian notes on page 26 of *Panzer Leader* that: "My work consisted of the setting-up and training of my new formation whose component units came from such diverse military backgrounds."

Under the instructions of General Lutz, Guderian prepared a book during the winter of 1936-37 which was published under the title *Achtung Panzer!*. This book told the story of the development of armored forces and outlined Guderian's ideas as to how the German armored force should be built up. *Achtung Panzer!* was developed from articles written by Guderian between 1925 and 1935.

Achtung Panzer! was intended to score points off institutional opponents and to gain the maximum resources for Guderian's own branch of the Army. A large portion of *Achtung Panzer!* describes the utilization of the tanks during WWI. The second half of the book is concerned with post-war military developments, especially armored fighting vehicle design and the organization of mechanized forces. *Achtung Panzer!* explains the thinking behind the operations of the panzer forces early in WWII. In addition, this book served as a textbook for trainee panzer officers during the war.

The first section of *Achtung Panzer!* describes how WWI degenerated into positional warfare. Guderian chooses an action that occurred early in 1914. The 2nd and 4th Cavalry Divisions, under General von der Marwitz, encounter the enemy near Haelen on 12 August 1914. The action at Haelen represents the commitment of cavalry in considerable force against defending infantry and artillery. The cavalry took significant losses without achieving their objective. One institutional enemy was the cavalry lobby.

Achtung Panzer! continues with Guderian's account of the role of tanks in WWI. From the accounts of tank warfare in WWI, Guderian draws three lessons. Tanks when used in penny-

packets have very little effect. Tanks should not be wasted on unsuitable ground. Finally, tanks provide the greatest surprise when used in mass formations. During WWII, the German Army under Adolph Hitler violated all of these rules.

After WWII, Guderian wrote *Panzer Leader*. The success and ultimate failure of the German Army should be traced to Guderian's ideas on tank employment. First, let's consider the success of German Army during the period 1939-1940.

Guderian wrote in *Panzer Leader* the following passage: "In this year, 1929, I became convinced that tanks working on their own or in conjunction with infantry could never achieve decisive importance." He further goes on to conclude: "It would be wrong to include tanks in infantry divisions; what was needed were armored divisions which would include all the supporting arms needed to allow the tanks to fight with full effect."

Several developments during the pre-war years worried Guderian. Tank brigades were raised to provide close co-operations with infantry divisions. The employment of tanks merely in support of unmechanized infantry was a reversion to the practice of 1916-1918. Tanks in this role would have some tactical utility but could have no operational impact.

The struggle for motorized vehicles between the cavalry and armored forces lead to the formation light divisions. The light divisions were a creation of the cavalry forces within the German Army. The light divisions were formed with two motorized infantry regiments, a reconnaissance regiment, an artillery regiment, a tank battalion, and various supporting elements. The light division's role was to provide strategic reconnaissance and a mobile fighting force. The light divisions proved ineffective during the Polish campaign because the single tank battalion was insufficient for offensive operations. After the Polish campaign, the light divisions were converted to armor divisions.

Before continuing on to the application of doctrine to war, let's examine the operation to incorporate Austria during the Anschluss. Guderian provides a useful summary of this operation in *Panzer Leader*. In March of 1938, Guderian commanded the XVI Army Corps. XVI Corps contained the 2nd Panzer Division and the Waffen-SS Division *Leibstandarte 'Adolph Hitler.'* This SS Division at this point was motorized infantry.

Guderian makes the following points about this operation:

a) The 2nd Panzer Division covered 420 miles and the *Liebstandarte Adolph Hitler* covered 600 miles in 48 hours. This proved the strategic and operational mobility of motorized formations.

b) Maintenance facilities were weak. This was remedied before the start of the war. Tanks require lots of maintenance to keep running.

c) Fuel supply was a fundamental problem. The German efforts in this area proved effective during the campaigns in Poland and France.

These points prove meaningful when compared to the performance of French armored divisions during the Battle for France in 1940. Consider the following points:

a) French tanks had such a short range their impact was limited to tactical operations.

b) The French never received an opportunity to correct their maintenance problems. French armor divisions proved very weak in this respect.

c) The French had severe problems in the area of fuel supply. The short range of French tanks required many refueling stops. A French armored division was caught while refueling during the 1940 campaign, and effectively destroyed without a fight.

Guderian commanded the XIX Army Corps for the invasion of Poland. This included 3rd Panzer Division, 2nd and 20th Motorized Infantry Divisions. Guderian managed to have the Panzer Demonstration Battalion (equipped with the latest Mark III and Mark IV tanks) and the Reconnaissance Demonstration Battalion assigned to his corps. The inclusion of these demonstration units from the training schools allowed the school personnel training to gain practical experience.

Guderian commanded from the front. An incident involving the 2nd Motorized Division is recounted on page 52 of *Panzer Leader*:

> During the night the nervousness of the first day of battle made itself felt more than once. Shortly after midnight the 2nd (Motorized) Division informed me that they were being compelled to withdraw by Polish cavalry. I was speechless for a moment; when I regained the use of my voice, I asked the divisional commander if he had ever heard of Pomeranian grenadiers being broken by hostile cavalry. He replied that he had not and now assured me that he could hold his positions. I decided all the same that I must visit the division the next morning. At about five o'clock I found the divisional staff all at sea. I placed myself at the head of the regiment which had been withdrawn during the night and led it personally as far as the crossing of the Kamionka to the north of Gross-Klonia, where I sent it off in the direction of Tuchel. The 2nd (Motorized) Division's attack now began to make rapid progress. The panic of the first day's fighting was past.

This demonstrates an important aspect of German armor doctrine. Leadership is from the front. To a certain extent, the German's excellent staff system allowed this type of leadership. This varies significantly from the doctrine of the British and French during the early phases of the war.

Guderian's greatest influence on the course of history came in France during the 1940 campaign. Although the Russian general Tukhachevsky (killed by Stalin before WWII) originated the "Deep Battle" doctrine, Guderian borrowed the concept and brilliantly implemented the Deep Battle doctrine in France. Some of the credit for the success of the 1940 French Campaign can be directly tied to a decision make by Adolph Hitler.

The original battle plan for the French Campaign was based on the Schlieffen plan of 1914. As Guderian notes on page 67 of *Panzer* Leader: "It is true that this had the advantages of simplicity, though hardly the charm of novelty." This involved a wheel through Holland and Belgium, then an advance on Paris. Unfortunately, a Luftwaffe officer-courier carrying a draft of this plan was captured on Belgian soil. Therefore, a plan proposed by General Manstein was used for the campaign.

The Manstein Plan consisted of a surprise armor attack through the Ardennes. The surprise would come because the terrain in the Ardennes is not ideally suited for armor warfare. The Allies played right into this plan by advancing into Belgium at the beginning of the campaign. The Germans then cut to the sea and basically surrounded the Allied armies in Belgium. At this point, the British managed to withdraw their troops without equipment through Dunkirk. Half the French Army was destroyed in this battle (including most of the mobile formations). At this point, the French had no option but to surrender.

The heart of the Manstein Plan was carried out by Guderian's XIX Panzer Corps consisting of 1st, 2nd, and 10th Panzer Divisions. In addition, the crack motorized infantry regiment "Gross Deutschland" was also assigned to the XIX Panzer Corps. The attack started on the 9th of May. Within five days, the XIX Panzer Corps crossed the Meuse at Sedan. Six days later (on the night of the 20th of May), a unit of the 2nd Panzer Division reached the English Channel south of Dunkirk.

Basically, Guderian forced the tempo of operations for this battle. The Ardennes can not be considered good terrain for armor operations. However, once the Meuse was crossed at Sedan, the Panzer Divisions entered good terrain for armor operations. This attack concentrated the bulk of German armor. Surprise was achieved and the Allies never recovered.

The victory in France had one very negative effect on the German Army. From this point on, Hitler interfered on the operational level. This meant that the German General Staff no longer controlled the operations of the German Army. During the Russian campaign, Adolph Hitler attempted to personally control the operations of the German armor. When Guderian complained, Hitler had him dismissed.

Although Guderian would return to service as the Inspector-General of Armored Troops and later as the Chief of the General Staff, his influence on operations was limited. The general decline in the armored force began in 1940. Hitler's love of numbers lead to the doubling of the number of armor divisions without an increase in tank strength. The Panzer Divisions that attacked Poland had over 400 tanks when full strength. The Panzer Divisions that attacked in the Ardennes in 1944 had about 100 tanks at full strength. The primary rule of concentration of armored forces was violated.

Guderian commanded nothing smaller than a corps during WWII. To determine the implementation of a tactic within a doctrine, the actions of commanders of smaller units becomes necessary. In this case, Hans von Luck's *Panzer Commander* provides the detail of small units in action.

Hans von Luck led the way into Poland in 1939. In 1940, von Luck was the vanguard of Rommel's thrust to the Channel Coast. In 1941, von Luck's unit reached the outskirts of Moscow. In 1942 and 43, von Luck served with Rommel in North Africa. In 1944, von Luck commanded the closest armored force to the Normandy invasion. In 1945, von Luck faced the Russians in Germany.

Major von Luck commanded the 3rd Panzer Reconnaissance Battalion in North Africa. The 3rd Panzer Reconnaissance Battalion operated on the flanks of the Panzer Army. This was mobile combat of the purest form. The Germans operated Schwerer Panzersphwagen (8 Rad) Sd Kfz 232 armored cars. This was an 8-wheeled armored car armed with a 20mm canon. The British operated Humber 4-wheeled armored cars armed with a 40mm canon. The Germans were more mobile while the British were better armed. In these conditions, tactics make the difference.

3rd Panzer Reconnaissance Battalion developed the "net" tactic. This tactic was used in flat terrain with a range of sight of more than 15 kilometers. The very fast and maneuverable eight-wheelers formed a large circle. The British Humbers and scout cars were then lured into the center. The British then received fire from at least two sides. This tactic usually worked, though sometimes isolated scout cars were lost to the powerful cannons of the Humbers. This tactic would also work with tanks.

This concludes our look at German armor doctrine before and during WWII. Next, an examination of Israeli doctrine provides further examples of the use of armor doctrine. Examining one armor doctrine will not necessarily supply all of the answers to the question of entering foreign doctrine into simulators. Other armies which exist in different political, social, and technological contexts will have a different doctrine. In order for a simulator to be effective, multiple foreign doctrines need to be available.

1.9 Israeli Doctrine

Information about the Israeli Army tends to be difficult to obtain through public sources. Considering the strength of Israeli intelligence agencies, some of the information coming out of Israeli should be considered suspect. Several good accounts of the Arab-Israeli Wars have been produced. These provide a useful point from which to study Israeli doctrine as applied to actual combat.

The Israeli Army regularly gets rated as the best army in the world. This rating comes from extensive combat experience and superior training. Some would say that this experience was based on facing second-rate foes, but the Jordanian Army and Egyptian Army may be considered to have equivalent combat experience as the Israelis up until 1973. In particular, the British trained and equipped Army provides a first rate foe. The Israeli Army armor force consists of regular and reserve troops. Generally, the regular Army has to hold defensively while waiting of the reserve to mobilize.

One of the more interesting methods of tracking Israeli doctrine comes from observing main battle tank (MBT) development in Israeli. Israeli Defense Force Armored Corps' founding father and the chief designer of the Merkava MBT is Major General (Res.) Yisrael "Talik" Tal. Tal volunteered into the British Army in 1942. He served in the 2nd Battalion of the Jewish Brigade and saw action in northern Italy against the Germans. In Israeli, Tal spent the early portion of his military career as an infantry officer. Tal was considered a natural at evaluating and refurbishing equipment.

In 1957, Tal was appointed the deputy commander of the Armored Branch. From 1960 to 64, Tal was personally involved in the 7th Brigade's day-to-day operations. Tal realized that Israel could not depend on foreign arms procurement during times of war. Therefore, Tal initiated the design and production of an indigenous Israeli MBT. Tal's objectives in designing and developing the Israeli MBT were threefold: to provide the IDF with it first ever state-of-the-art MBT; to eliminate the threat of an embargo; and to build a tank suited to Israeli requirements.

During the 1973 War, Israeli lost 1,492 tank soldiers. Many of these tank soldiers were veteran reservists which seriously weakened the IDF Armored Corps. Tank design concerns balancing three elements: protection, firepower, and mobility. The design of the Merkava optimizes crew protection. Mobility and speed proved less important because of the terrain where the Israeli Army fought (particularly the Golan Heights). Firepower for the Merkava was also a lower priority.

The Merkava started with a unique design. The engine was placed in front of the crew compartment (the engine shields the crew compartment). A diesel engine was selected (to lower the risk of fire). The tank's design incorporates a low slope configuration to the hull and turret front (the steeper angle cause projectiles to glance off). The Merkava possesses a huge rear escape hatch for easy bailing out by the crew. Three additional factors contribute to crew survival: a small silhouette when in a firing position, lack of flammable materials in the crew compartment, and the storage of ammunition under the turret ring.

The cardinal rule of armor warfare has been the first to shoot wins. The Israeli's have reinforced this in their training by increasing their first hit percentage to amazing heights. However, by making their MBT tougher to kill, the Israeli's live to fight another day. To a large extent, the Israeli Army has retained control of the battlefields they have fought on. This allows the Israelis to recover a higher proportion of their lost MBTs.

Another important change in doctrine was required by the losses suffered in the 1973 war. The lost of so many veteran tank crews that replacement crews became imperative. These crews were required on the front lines immediately. The Israeli Army took tank crews just completing basic armor training and assigned them to a veteran crew. This allowed the new crews to learn quickly while on the front lines and provided some relief to the veteran crews already serving on the front lines.

The cost of the losses during the 1973 war came back to haunt the Israelis in Lebanon during 1982. First, the lack of experience and loss of junior officers hurt the Israelis. Second, the very

size of the Merkava made the tank difficult to maneuver through the closed terrain in Lebanon. Third, Israeli doctrine concentrated on the open country tank battles. When fighting in close terrain, combined arms doctrine becomes of supreme importance. This lesson was learned in the jungles of Southeast Asia during WWII.

The Israelis have also recovered many of the MBTs that their enemies have lost. This has lead to the Israelis converting ex-Soviet MBTs to armored personnel carriers (APCs). The thick armor of a APC built from a MBT provides much greater protection than the thinly armored APCs used by most armies. This practice goes back to WWI. In WWII, the Canadians converted their Ram tank into Kangaroo APCs which were used across Northern Europe with the 79th Armored Division.

A good example of Israeli doctrine at work comes from Force Tiger during the 1973 war. Captain Zamir commanded Force Tiger which consisted of seven tanks. Elements of the Syrian 43rd Armored Mechanized Brigade moved towards Force Tiger's killing zone. Force Tiger waited until the Syrians were 30 meters away. The Israeli barrage so surprised the Syrians that they immediately attempted to retreat. However, Captain Zamir had placed two tanks in a blocking position. The Syrians lost 20 tanks in 45 minutes. The next day, Force Tiger (reinforced by the 74th Battalion) eliminated another 20 tanks from ambush. Not a single Israeli tank had been hit and not a single Israeli soldier received a scratch.

2 PHASE I RESULTS

2.1 Graphical Tactics Language

During the Phase I tactics investigations, it was determined that the most natural medium of tactical communication for humans is schematic drawings. This led us to develop a graphical based editor for creating and updating tactics. It allows the user to graphically describe tactics in terms of necessary terrain, battle lines, and movement conditions. The language is a schematic drawing of the tactic, supplemented with parameters and constraints between the graphical objects. After entering the terrain configuration the tactic needs, and the specification for how to use the terrain, the user is prompted for allowable ranges for the terrain sizes and their relationship with other terrain features. The input is the tactics drawing the user enters, the output is the machine readable text version of the tactics language.

2.2 Machine readable text file version

The machine readable version of the tactics language is a text description of a tactic. The tactics editor produces a text file in this language for each tactic entered. The tactic implementation module uses these text files as its data base for tactics. These files are the medium of communication between the tactics editor and the tactic implementation module. It has the capability to rigorously describe a tactic, and the terrain configurations necessary to execute the tactic. The technical approach is a constraint satisfaction problem. The language must describe the constraints the terrain must satisfy to make the tactic possible. This is specified in terms of terrains which must be present, the necessary range size of the terrain, the necessary range of distances to other terrain features, and the necessary range of angels between the pertinent terrains and the expected enemy avenue of approach. In addition there are constraints about distances to the enemy avenue of approach.

After the terrain configuration necessary for the tactic has been specified in terms of these constraints, the actual tactic needs to be specified. This is done by reference to a terrain constraint. For example placing a battleline 50 meters behind a mountain of at least 200 meters parallel to the expected enemy of approach. The actual syntax of the text based language is complicated and intended to be machine created and machine read. Deployment of the tanks in the tactic is described in terms of battlelines placed in the tactic editor. Battlelines are specified with respect to a terrain feature necessary for the tactic. If no terrain features are necessary, the battlelines are specified with respect to a "ghost" terrain, which is simply a terrain stand-in that does not need to be present in the final terrain layout. The movement for a tactic is specified in terms of enemy contact with a battleline, not necessarily the battleline that is moving.

2.3 Execute Tactics on Arbitrary Terrain

We found that we were able to appropriately identify terrain, identify tactics that were appropriate for the terrain, and properly execute tactics on this terrain. This requires the mapping from schematic terrain concepts to actual terrain instances available in the current terrain database. It also requires taking the enemy avenue of approach into account, this determines if the terrain is at the appropriate distance and at an allowable orientation. It also requires that the tactics be flipped, rotated, reflected, and stretched to determine if there is any way the tactic can be made to fit the current circumstances. The parameters for how much stretching are allowed are set along with the schematic tactical drawing in the tactics editor. This requires geometrical image analysis for determining if a tactic's constraints are in any way satisfied, and for properly orienting the tactic on the terrain.

2.4 Tactics Selection

Many tactics may be permissible on any given terrain. Selecting which applicable tactic to execute can be handled in a few ways. The operator may be presented with an ordered list of tactics, this leaves the tactic selection up to the SAF operator. This list can be filtered to show only permissible tactics, and it can be ordered to show the system's ranking of the best tactic.

Alternately, the system can simply pick the best tactic, this is determined by a case based reasoner that compares factors in the current environment with factors in the tactic. For instance a tactic might work well in fog, or in engagements of a certain size, or against a certain set of anticipated enemy assets. In Phase I the tactic was selected according to how much use it made of the available terrain, with tactics heavily dependent on terrain taking priority over tactics that don't make use of the terrain but were still applicable. A certain degree of variety could be put into a final system, with a random factor having weight in determining the tactic to be executed. This would lead to SAF that are less predictable, and would give trainees exposure to a wider range of tactics.

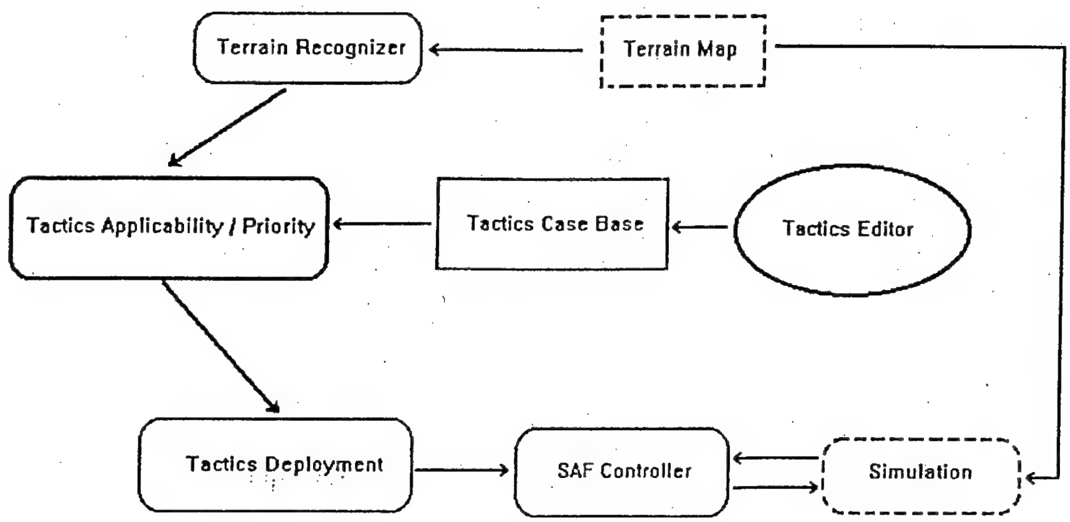
2.5 SAF Controller

After the tactic is placed on the terrain, the simulation execution needs to be monitored, and all of the tactical movements have to be executed. This monitoring and SAF control are the only computations that need to be done while the simulation is running, and thus is the only computation load the system puts on simulation resources. The movement triggers for the Phase I system are all firing events so this information has to be extracted from the simulation. Given that a tactical movement is to take place, the system has to determine where to send each tank involved in the tactic, this information is derived from the battle lines specified in the tactic. There are no computations for each unit with every other unit (like line of sign calculations in a simulation) so the computational complexity is O(n) where n is the number of units. This proved to be much less than other computational considerations in the simulation environment.

2.6 Terrain Recognition

The tactics are represented in terms of terrain pertinent to the tactic. This must be compared to the actual terrain available to determine if and where tactical match-ups occur. This requires that terrain entity information is available for the current terrain database. The terrain requirements are not exact, so a general, idealized interpretation of the terrain is sufficient. This need was met in Phase I with a simple terrain recognition module that made general classifications about terrain objects and dimensions from elevation data. In Phase II, because of the more complicated terrain and the limited number of terrain databases available, we anticipate doing the terrain recognition by hand and then supplying the classification information to the tactics matching module. We will also investigate existing terrain recognition capabilities available with the databases in the simulation environments we interface with.

3. PHASE I PROTOTYPE



Terrain Recognizer - This software takes elevation data from the terrain map and produces identifications of the terrain features present.

Terrain Map - The terrain the simulation runs on, it provides a bitmap for the simulation background and elevation data.

Tactics Applicability / Priority - This module determines what tactics are applicable given a terrain identification. It also ranks the tactics for anticipated effectiveness.

Tactics Case Base - This data is a set of machine readable files produced by the tactics editor.

Tactics Editor - This is the graphical software users used to enter end edit tactics.

Tactics Deployment - This takes the chosen tactic and deploys the units in their initial battle formations.

SAF Controller - This monitors the simulation and executes movements as dictated by the tactic.

Simulation - This is the simulation environment that the system runs in.

3.1 Graphical Tactics Editor

The Tactics Editor for the Army SAF project was programmed in the Kappa-PC development language. It allows the user to program tank tactics in a graphical environment, using three kinds of objects:

- Enemy avenue of approach (EAA)

  Represented by a ray. The user constrains the minimum and maximum number of tanks, 0 and "unlimited" inclusive.

- Terrains

  Represented by circles which graphically indicate mountains, hill, minefields, and lakes. The user must specify minimum and maximum size, minimum and maximum distance to EAA, and orientation to EAA. This last constraint extracts the important dimension of size in relation to the EAA. In addition, if distances between terrains factor into a tactic (e.g. in order to ambush an enemy traveling between two mountains, the mountains should be fairly close together), the user may provide this additional constraint by associating the terrains and indicating their minimum and maximum distance from each other.

- Battlelines

  Represented by line segments. The user specifies the number of tanks at the start of the battle, length of the battleline, associated terrain, and distance to the associated terrain. In the case of a desert scenario with no terrain, the user employs a ghost terrain to specify relative distances of battle lines. If the number of tanks available for a battle is not exactly what the tactic expects, the tanks are placed on battlelines according to the ratio of the programmed tactic.

This information is completely user specified, so that the editor merely outputs exactly what the user entered -- with the one noted exception of angle constraints which are calculated from the drawing. In addition, the user can also specify movement between battlelines which occurs on three conditions: after firing, when another battle line fires, or immediately.

This graphical representation must then be exported into a tactics language which is used by the simulator to select the best tactic for a given terrain, place tanks on battle lines, and move the tanks during the engagement. The major hurdle here is to output not only the user specified data listed earlier, but to capture the positions of tactic objects relative to each other to allow for maximum flexibility in matching tactics to terrains. To this end, the Tactics Editor uses the enemy avenue of approach (EAA) as a fixed line to determine:

- angle of the EAA with respect to terrain positions

  This calculation ensures that not only do the terrains match, but the EAA is traveling the correct path for a given tactic to be employed. The user may also specify an accuracy leeway for his drawing to allow for broader matching of tactics.

- positions of battlelines relative to associated terrains
  Ensures battlelines are placed correctly about their associated terrain with respect to the EAA.

- angles of battlelines relative to the EAA
  Places the battleline at the correct orientation to the EAA.

All calculations were done by treating lines as two points, terrains as single points, and then using cross products to determine the appropriate angles.

The information is exported as a simple text file in a format which can then be read by the simulator.

3.2 Tactics Implementation and SAF controller

This part of the tactics system is implemented in Borland C++ 5.0, it central technology is a constraint satisfaction determination, it was coded using a C++ object oriented approach. This module takes the tactics files produced by the tactics editor and the terrain features produced by the terrain recognition module and makes a determination of the terrain constraints as specified in the tactic are met by the current terrain. It does this for each tactic in the tactic data base and produces a list of applicable tactics, a case base weighted determination is then made among the allowable tactics to determine the tactic most likely for success. Currently, tactic selection is based on how extensively the tactic makes use of the available terrain with that make extensive use of the available terrain rated as having a higher probability of success.

Terrains were specified by a bitmap. The simulation runs on this same bitmap. The terrain bitmap was processed into a terrain description file in which the terrain features are classified. This is one of the inputs to the C++ program. The terrain is described by the start point and endpoint of the enemy avenue of approach (EAA) and by terrain objects such as lakes, mountains, hills, and minefields and their coordinates.

The other input to the program is the tactics data base, created by the Tactics Editor. The tactics files describe the terrain constraints that each tactic must meet. These constraints include distances to the EAA and distances between terrain objects. Also included in the tactics files are descriptions of the user-specified placement of the battlelines with respect to the terrain objects. When a tactic is chosen, these battlelines are deployed.

Specifying constraints in the Tactics Editor is optional. The user can specify as many as they want. They include as many terrains as are required by the tactic and as much information, such as distance requirements, that are necessary for the tactic. The C++ program would take all the tactics files and check whether their constraints were satisfied.

The basic algorithm is to assign each tactic terrain element to a terrain object in the specific terrain. Once the assignments are made, the program determines whether constraints specified in the tactics file were met by that assignment by checking whether distances to the EAA and to the other terrain objects matched. It would iterate through each possible assignment until one was successfully matched.

The program would then eliminate as possibilities the tactics whose constraints were not met, for example if the tactic required more terrain elements than were in the specific terrain or the distances did not match up. Of the successful tactics, the program would chose the one that was the most heavily constrained, meaning that more terrain objects and more distances were specified in the tactic.

If none of the tactics matched up, the program would chose either a tactic for a ghost terrain, or if no ghost terrain tactic existed, no tactic would be chosen and no battlelines would be deployed. Ghost terrain tactics require no terrain objects and the ghost terrain is mapped to the center of the bitmap. Battlelines are deployed around it as specified by the tactics file.

Once the program has chosen the best tactic, it deploys the battlelines onto the terrain. The tactics files specify which terrain objects the battlelines are associated with. They also specify a battleline start point with respect to the center of the terrain. An angle from the EAA and a distance completely specify this. Then the files would specify which direction the battleline would be built in, given as an angle to the EAA. For example, a 90 degree angle would say that the battleline should be built perpendicularly to the EAA. Using this information, the program places battlelines on the bitmap around the terrain objects the tactic was mapped onto.

Once the battlelines are placed, the simulation begins. While the simulation runs, the program keeps track of whether battlelines should be moving and calculates the new coordinates for the tanks.

3.3 Simulation

The simulation is for demonstration purposes only, it will be replaced by the current military simulation once the SHAI tactics system is integrated with ModSAF and CCTT. The simulator is simply a tactics display medium, the tank parameters and capabilities are not accurate. It takes commands modeled after ModSAF commands, and produces only information available in ModSAF. This to facilitate Phase II integration with ModSAF. If the simulator did accurately reflect reality, the system could be used to investigate the effectiveness of tactics. Changes in tank capabilities (speed, range, fire rate, etc.) have a definite effect on the utility of tactics in the tactics data base. The simulator is implemented in Borland C++ 5.0 by a subcontract to the Research Development Corporation (RDC) in Washington DC

3.4 Terrain and Tactics Implemented in Phase I

For the Phase I demo, we have selected the followings tactics to represent:

Flat Desert .

1. Flanking
2. The Net
3. Bait and Switch

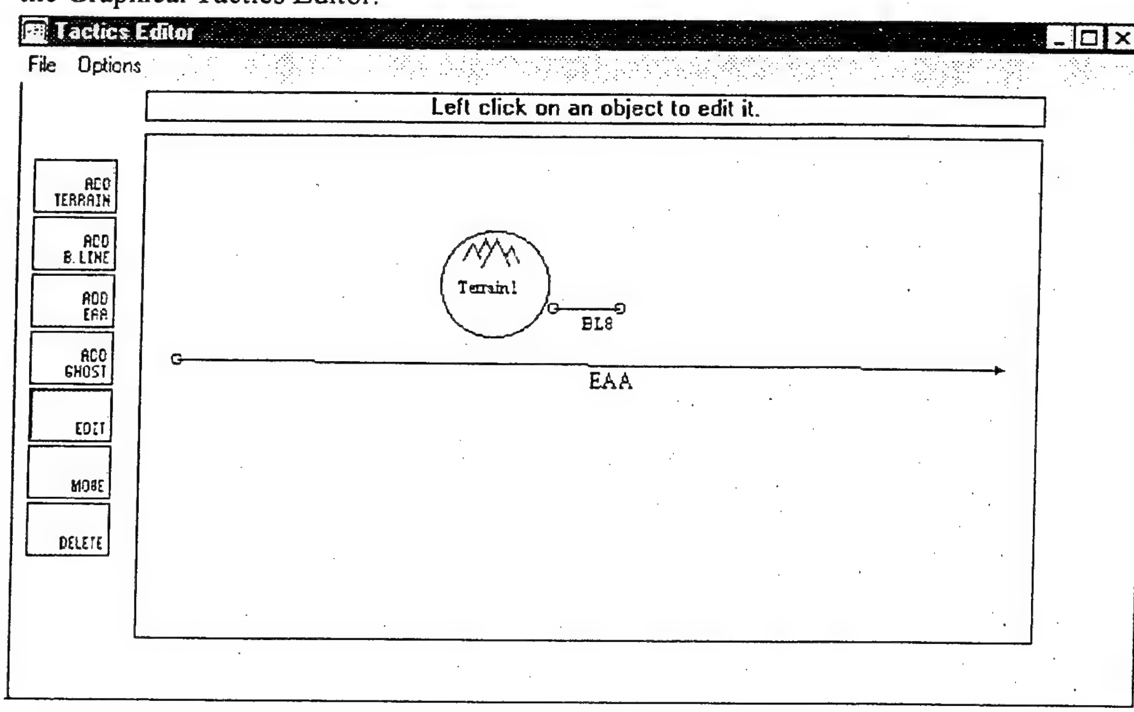
Low Rolling Hills/Arid

1. Skirmishing
2. Channeling
3. Landmark

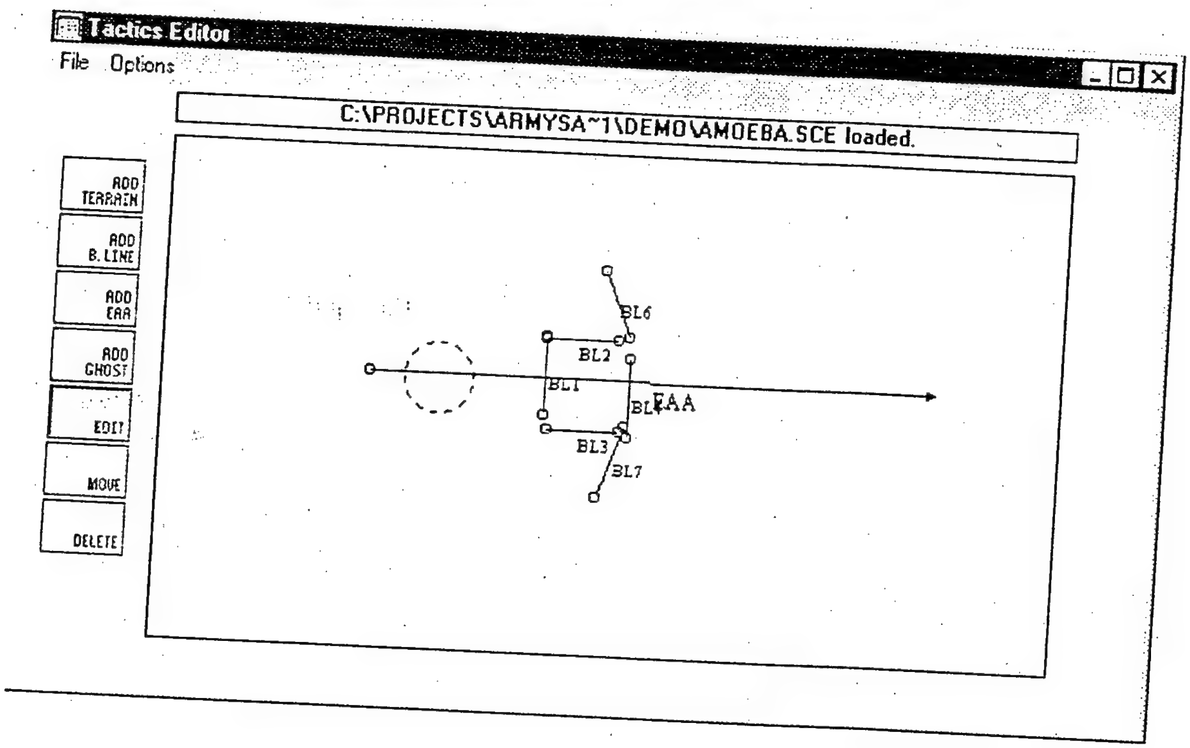
The Flat Desert tactics have been drawn from the German and British experience in the Western Desert in WWII. The Low Rolling Hills/Arid tactics come from battles fought in the Middle East during and immediately following the Yom Kippur War.

3.5 Demonstration Sequence

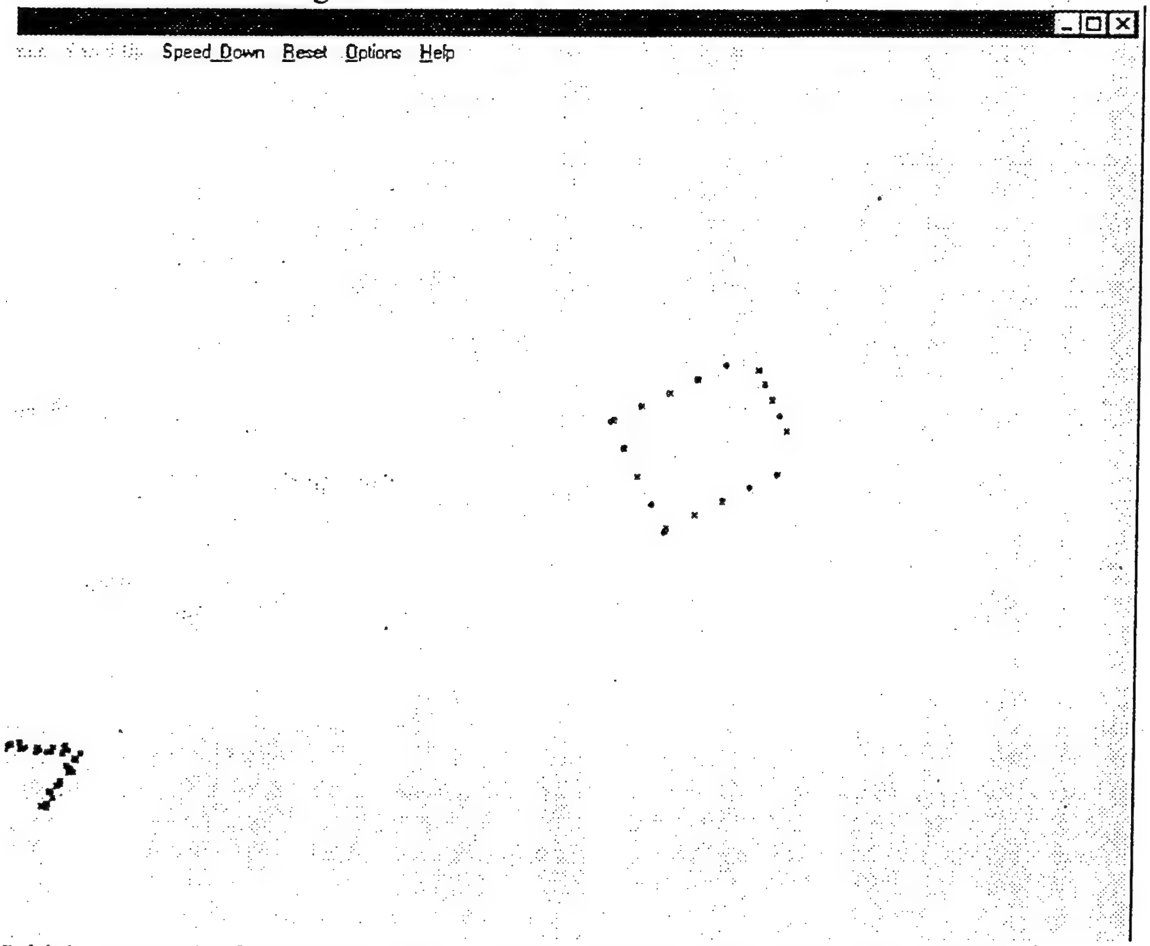
The demonstration sequence starts with a new tactic being entered by the user, the tactic is a simple ambush where a battleline is placed behind impassable, concealing terrain. This is done in the Graphical Tactics Editor.



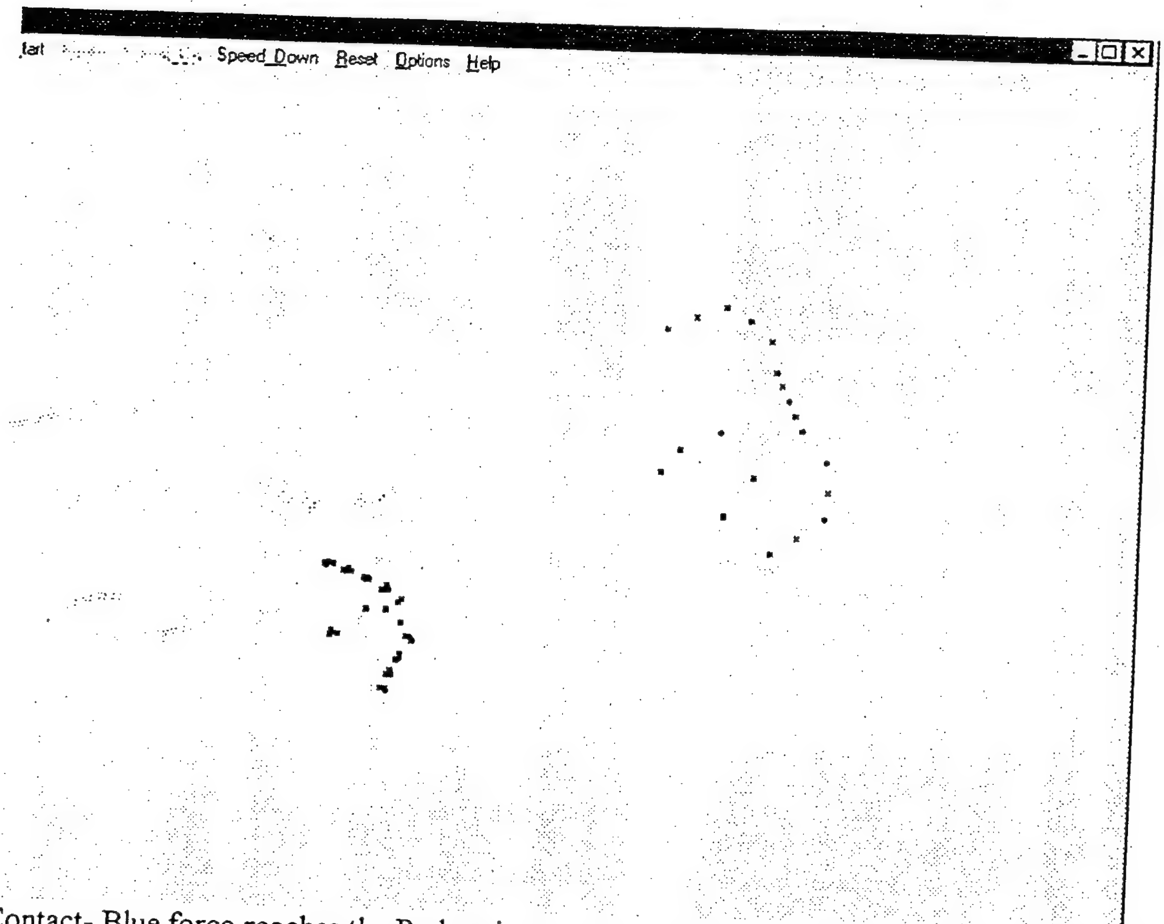
This tactic is added to the tactics case base. Next the simulation is run with a desert terrain. The previous tactic is not applicable because it requires a mountain, but a desert tactic called "The Net" is satisfied. It was used by the Germans and British in North Africa during WWII. The tactic's representation in the editor shows the initial battle positions, and the tactical maneuvering positions.



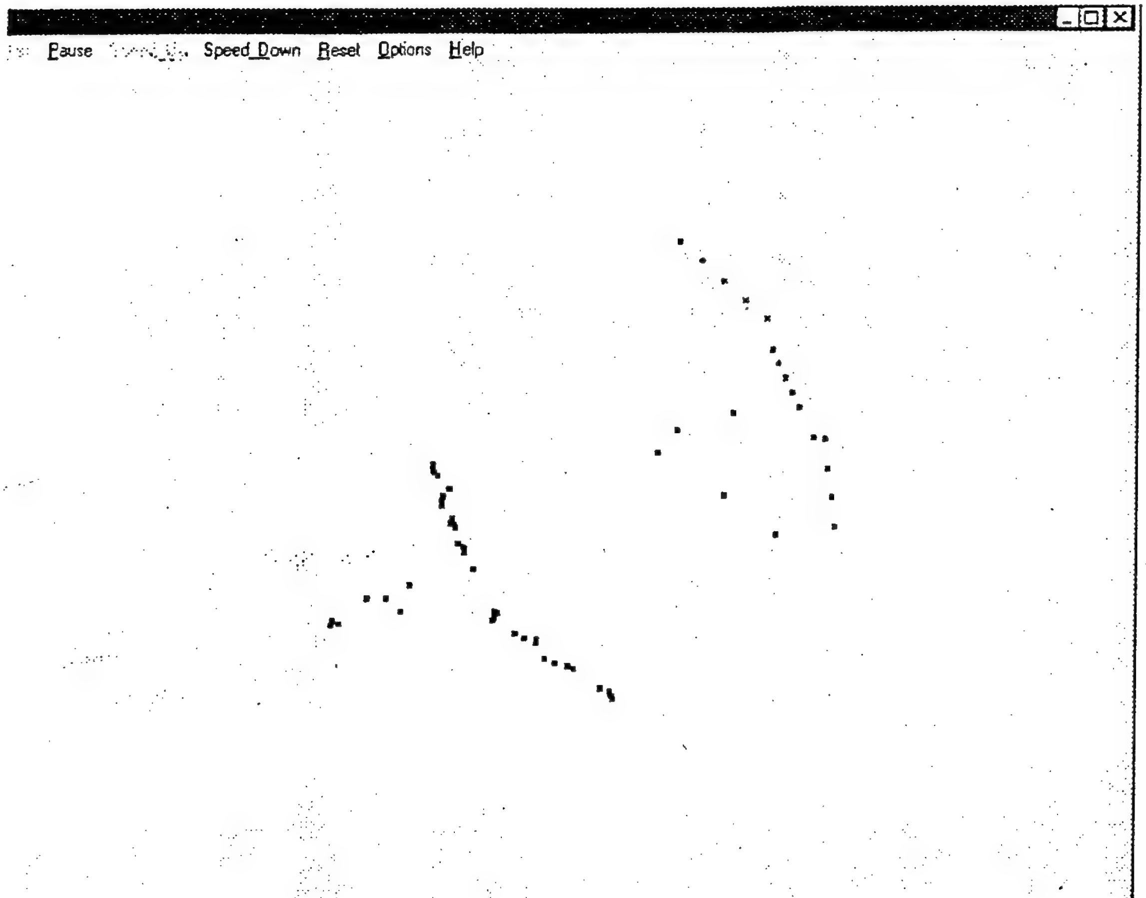
This tactic is called up and oriented to the expected enemy avenue of approach, the tactic then executes in the following manner.



Initial setup - The forces are arrayed in a square as specified in the tactics editor

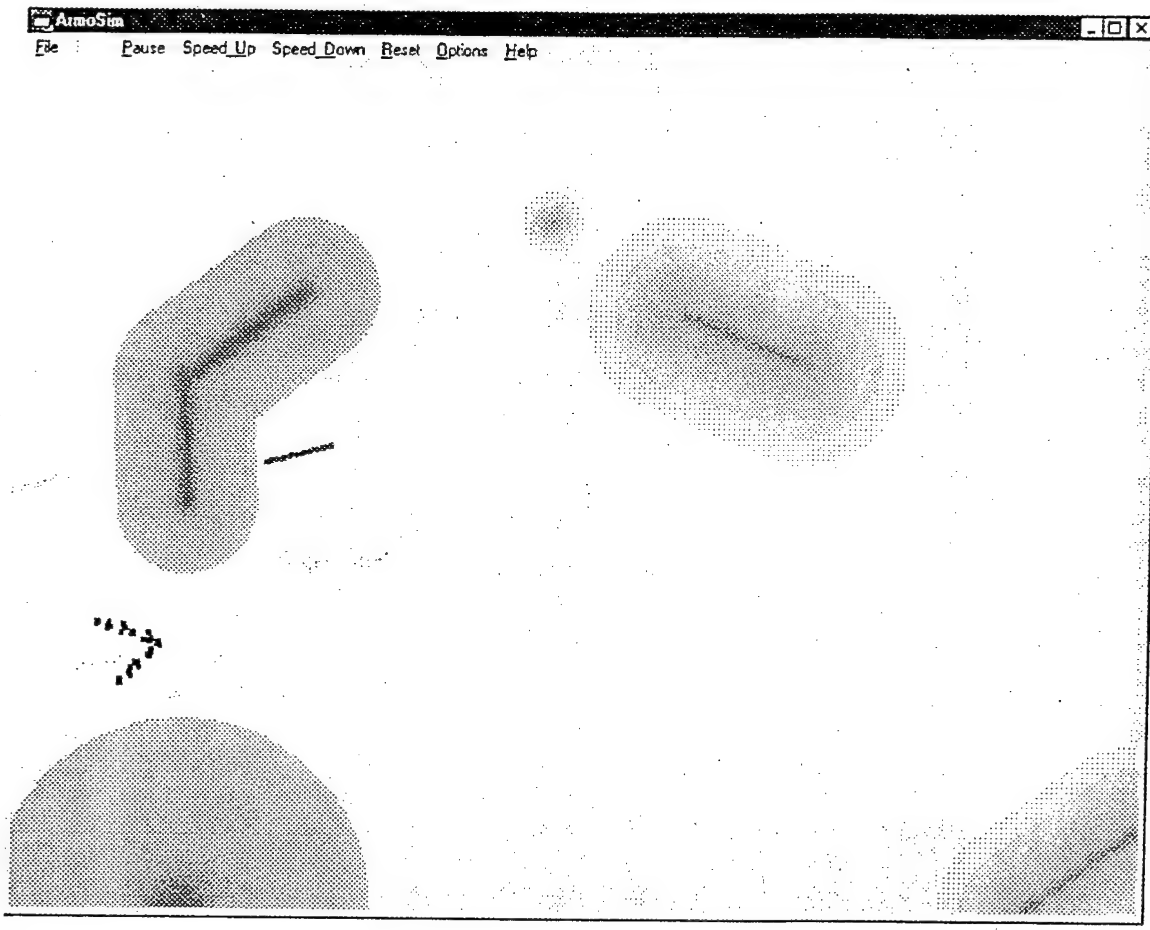


Contact- Blue force reaches the Red perimeter and the Red Force falls back to establish a unified battle line.

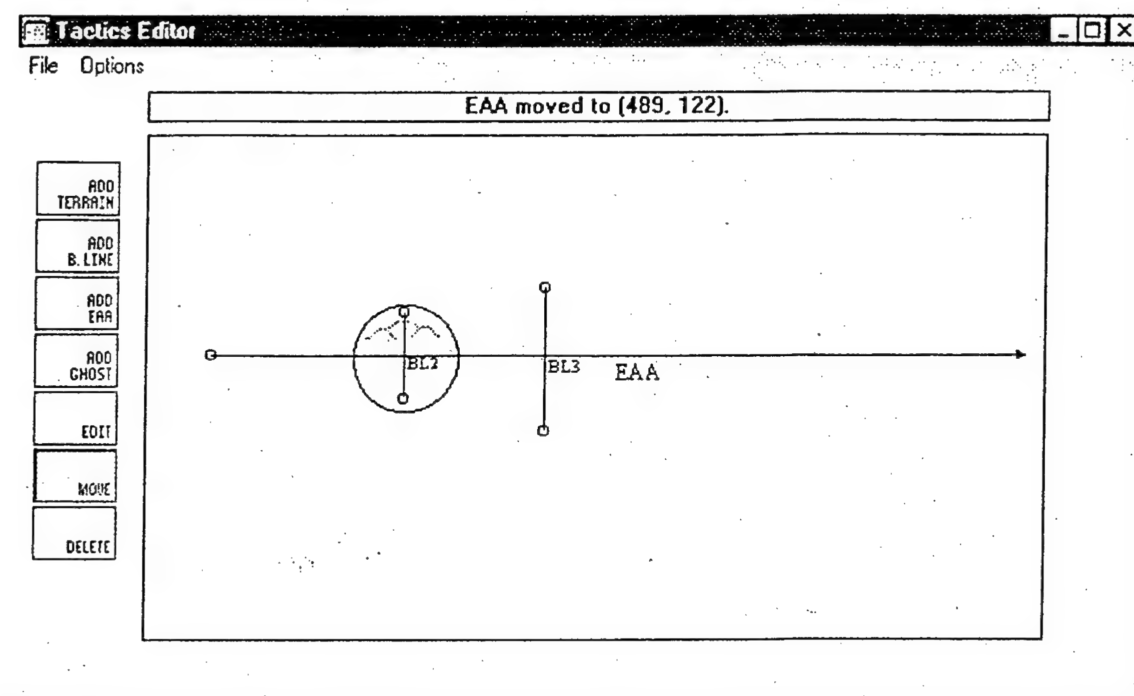


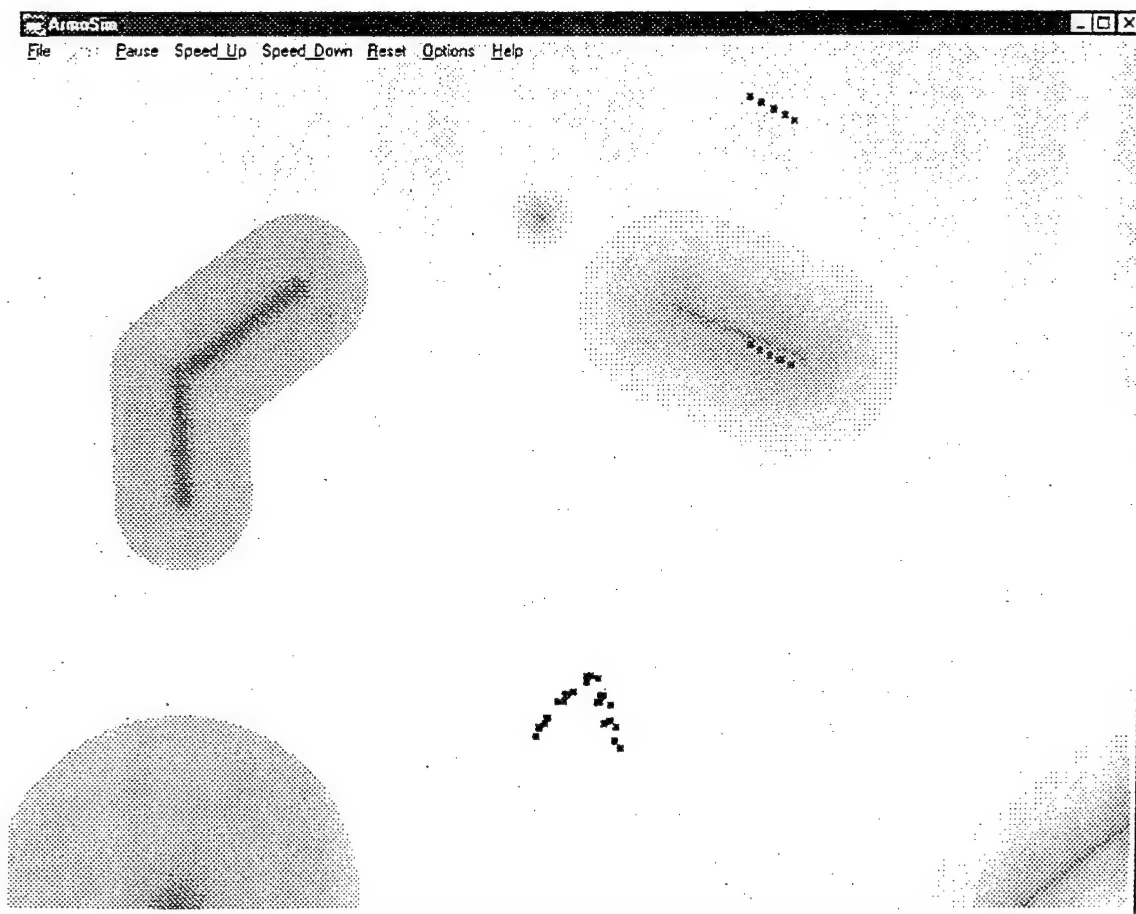
Engagement termination - The Red force reaches the line and the simulation runs until a winner is decided.

Next the terrain is switched to a rolling hills setup. The tactic retrieved in this terrain depends on the enemy avenues of approach. When we direct blue force through the choke point defined by two mountains, the system recognizes the opportunity and sets up the ambush which was entered as the first step. This shows the expandability of the system by the dynamic inclusion of new tactics.



When we change the enemy avenue of approach to avoid the mountain choke point, but to go over the central hill, the ambush tactic is invalidated, but a skirmishing tactic is satisfied. The following images are dumps of the skirmishing tactic in the Graphical Tactics Editor, and what the tactic looks while executing on this terrain. The tactic entails lining up on a hill, firing on an approaching enemy, and then retreating to a main battle line. This forces deployment of the enemy slowing them down, and it also inflicts damage with minimal risk to the unit.


Tactics Editor
File Options
EAA moved to (489, 122).
ADD TERRAIN
ADD B. LINE
ADD EAA
ADD GHOST
EDIT
MOVE
DELETE
BL2
BL3
EAA


File Pause Speed_Up Speed_Down Reset Options Help

4. PHASE II DESIGN

Much effort has been put into the problem of creating realistic, flexible, expandable, portable, and easily alterable SAF behaviors. Stottler Henke Associates, Inc. (SHAI) proposes the development of a graphical SAF behavior language for the representation and editing of SAF behaviors by domain experts. After editing, the user will be able to save the tactic in executable form which will be able to control SAF in simulations (CCTT or ModSAF) or in text form as a CIS document. SHAI also proposes interfacing the tactics created by the editor to established simulations running with ModSAF and CCTT in order to test them in simulation. This will be a way to investigate and validate SAF behaviors by actually running the tactics entered by the tactics experts. In addition to tactic validation, the graphical tactics editor will export tactics in a form that can be interfaced to different simulation environments, simply by creating an interface controller for each simulation. This results in a mechanism for creating common, portable SAF behavior on different systems. Another benefit of the SHAI behavior editor will be the ability to output tactics in the form of Combat Instruction Sets (CIS) so there is an automated way to enter tactics, test them on a variety of systems, and automatically generate CISs. The center piece of this system is the graphical tactics editor, a proof of concept of which was developed in Phase I. The other elements of the system are the interface modules to ModSAF and CCTT, which will be updated and expanded versions of the SAF controller in the Phase I system. In Phase II, SHAI will investigate the full representational requirements for the entry of tactics in the Graphical Tactics Editor. We will implement the user friendly graphical editor, and the ability to output CIS from the editor. We will also implement the SAF control interfaces to ModSAF and CCTT which will provide multiple tactics testing environments and SAF cross-simulation commonality.

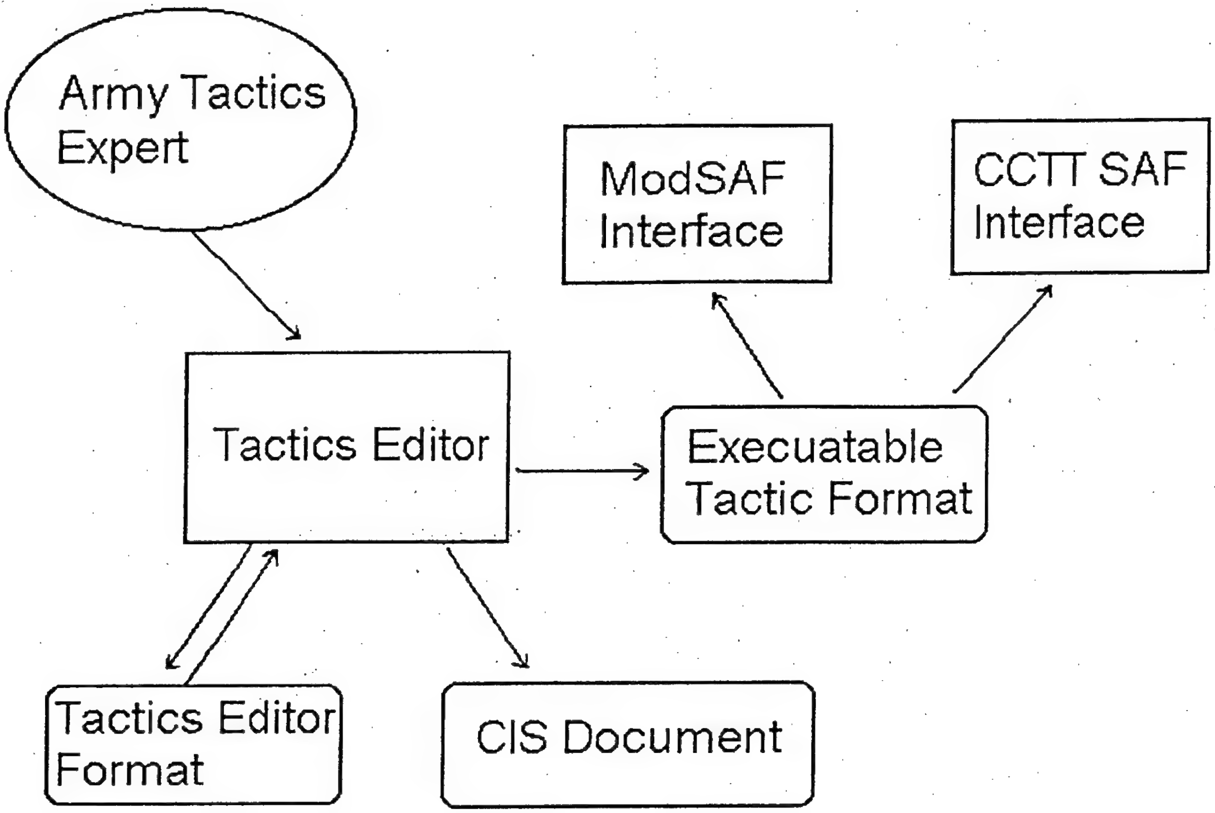


Figure 1

In Phase II we will develop the Graphical Tactics Editor and SAF controllers based on our results from the Phase I system. We will also develop the ability to output Combat Instruction Sets from the graphical behavior description. Domain experts will be able to edit behaviors in a structured, yet user-friendly environment. This structure will allow software to translate from the graphical language into a variety of formats, an editor format which will allow users to save and restore tactics for multiple editing sessions, a CIS format, and an executable format which will be the basis for controlling the SAF in the interfaced simulations. Since tactics are often conveyed visually through diagrams, the most natural SAF behavior language is also visual. It should resemble the diagrams in the approved Army doctrine documents, and use the same symbols. Additionally, an animation capability to illustrate timing issues or reactions to certain events might also be helpful.

After development, the general SAF tactics representation schema will be used in the following way. The user enters the tactic into an easy to use graphical editing tool, the SAF behavior language is itself graphical, so entry consists of dragging and dropping icons (which correspond to abstract objects in the simulated world such as battlelines, terrain features, avenues of approach, etc.), making links between them, and describing the constraints or primitives with each link. The user will also be able to use animations to specify the timing for situations where timing is critical. For instance pulling a tank icon along the enemy avenue of approach, then specifying the tactical reaction to the exact status of the battlefield. There will also be the ability to specify the flow of a simulated battle from tactic to tactic. The user will be able to specify conditions under which the tactic should change formation into another tactic. There will also be the ability to specify some

tactical transitional parameters and methods. When the described conditions for a tactical change are met in a simulation, the SAF will automatically flow into the next specified tactical formation, using the transition methods described in the language. This will also allow domain experts to analyze what tactics flow naturally from other tactics. It will also allow the complete analysis of a multi-tactic battle scenario.

The graphical SAF behavior language describes SAF behavior in abstract terms. The enemy tank represented in the diagrams represents any enemy tank meeting the specified criteria, the hill in the diagram represents any hill which meets the specified constraints, etc. The tactical representation which is generated from this representation must search its area of a battlefield for particular simulated objects which match the parameters of the abstract ones in the language. Once a match has occurred the relevant objects which meet the constraints are bound to the abstract objects in the behavior language and the tactic is setup and executed accordingly. For mobile and changeable objects, like tanks, this must occur during run time. For permanent objects, such as terrain features, this matching can occur off line, for a particular terrain, before the simulation is run. Since terrain matching is computationally intensive, it should be done off-line for a set of terrain data, saving the results for subsequent simulation executions on that terrain.

This single intuitive representation of tactical behavior can then be used for multiple purposes. It can be used for the automatic creation of CIS documents complete with figures, and for the creation of a tactic representation that can be run in different simulation environments. This will lead to many advantages in tactics validation, the rapid implementation of new SAF behavior, automatic creation of CIS, and implementation of common SAF behavior in multiple simulations.

The graphical behavior editor will make the problem of tactics validation much more tractable. With this tool, tactics will be easy to specify. These tactics can be output into their executable format and then run on various simulations. The graphical behavior editor will be able to encode both offensive and defensive tactics. Domain experts can quickly specify tactics then run simulations to investigate the results of their tactics. The user can vary simulation parameters and the strengths of each side to analyze the tactic. They will be able to determine which tactics work well against other tactics, what conditions a tactic works well in, and how the effectiveness of a tactic varies with assets available. This rapid feedback will allow users to investigate many different tactics, many different tactical combinations, and fine tune the tactic parameters. This will allow for easy validation of tactics and investigations of the optimal situations for the tactic.

Another benefit of the graphical tactics editor is the rapid implementation of new SAF behavior. Instead of writing code for each new SAF behavior, new behaviors can be created by simply entering the behavior in the user-friendly, high level behavior editor. This graphical description of the behavior will be interpreted by the editor and automatically output in a form that can be used to control SAF. This is a much quicker avenue to new SAF behavior than coding behavior from standard programming languages.

In addition to the efficient reliable creation of SAF behavior, the Graphical Tactics Editor will greatly facilitate and standardize the creation of Combat Instruction Sets. The option of saving the tactics in CIS form will be available. Phase I showed that graphical diagrams are the most

natural representations for tactics. We will be able to convert this graphical representation to both CIS format and a format suitable for SAF control. This will make CIS production easier, faster, and will make the SAF behaviors automatically correspond to the Combat Instruction Sets. It will also standardize the CIS production.

Another benefit of a SAF behavior language and editor is that the tactic output could be supported for multiple simulations. The behaviors would only need to be described once in the high-level SAF behavior language, this description could be used as the basis for SAF behavior in many simulations. This contrasts sharply with the current situation where unique software is developed for each different simulation, unit, and weapons system. Currently each unit's behavior must be implemented for each simulation. Implementing SAF behavior based on a common behavior representation produced by the Graphical Tactics Editor will lead to SAF behavior consistency.

An example run through the system would be for a domain expert to come up with a new tactic. We would then enter the tactic by creating a schematic visual representation of it and filling in some parameters that the system prompts for. He would then save the tactic in the executable format and run it in the simulation environment, he would then be able to go back and tune the tactic until it is satisfactory. Finally he could then save the validated tactic description and automatically create a corresponding CIS for it.

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